PC BASED SCADA SYSTEM
FOR REVERSE OSMOSIS
DESALINATION PLANTS

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
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(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

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TRONOH, PERAK

December 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Omar Mohamed ElSayed Torky

ABSTRACT

Reverse osmosis Desalination plants are a widely used application of water treatment engineering all over the world. Therefore devising control systems for these plants is a must in our modern automated industrial world as different systems has been devised yet their technology became obsolete by time. On the other hand complicated and over rated control systems are not convenient to use with these types of plants, especially for remote areas. Therefore, coming up with a monitoring system to monitor and control a Reverse Osmosis water treatment plant is a convenient solution with computer based software. The plant can be monitored using a PC enhanced with industrial automation software like LABVIEW® and a data acquisition card to build up a SCADA system for the water treatment plant. This work illustrates the structure and the installation of a flexible and low cost SCADA system. An ordinary PC with the appropriate interface and software operates the system. The system is installed to a lab scaled water plant which is designed and built. The system has proved the practicality of PC based SCADA systems over the conventional control systems.

ACKNOWLEDGEMENTS

“In the name of Allah, the Most Gracious, the Most Merciful.

Listing all the names of people who contributed to the fulfillment of this work wouldn’t be an easy job in fact the papers won’t help nor the ink will; yet I would like to mention my parents, Brig Gen. Mohamed ElSayed Torky and Mrs. A.Omran whom without their guidance I wouldn’t have come to be the man I am today, My dear sisters as well M.Torky and N.Torky for being there when I needed them.

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Thank you all”

-The Author

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LIST OF ABBREVIATIONS

SCADA	: Supervisory Control And Data Acquisition.
PC	: Personal Computer.
RO	: Reverse Osmosis.
TDS	: Total Dissolved Salts.
PCMCIA	: Personal Computer Memory Card International Association.
I/O	: Input and Output.
DAQ	: Data Acquisition.
DAS	: Data Acquisition Systems.
EPICS	: Experimental Physics and Industrial Control System.
LED	: Light Emitting Diode.
VI	: Virtual Instrument.
PLC	: Programmable Logic Controller.
TFS	: Tensile Fabric Structure.
3D	: Three Dimensions.

CHAPTER 1
INTRODUCTION

This chapter covers the project background, the problem statement and the objective of this final year project.

1.1 Background

Reverse Osmosis water treatment since its development in the 1970's has been marked one of the most important water treatment solutions in the modern age. Using this technology has given a lot of people around the globe the opportunity to fulfil their needs of water in different prospective and as we know as water has been always the secret of this life, it was important to monitor our resources develop them and gain control of their distribution and treatment in order to make the optimum usage of this valuable resource.

With modern control technologies, different systems have been devised to monitor and control the process of water treatment. Conventional control systems have been widely used. However, by these technologies becoming obsolete and new technologies emerging with a high end control and monitoring. These technologies started with high cost yet by time gained reputation and engineers were able to reduce the cost of the new technologies.

The SCADA (Supervisory control and data acquisition) is one of the high end technologies of the modern control systems. Its advantages are countless and its ability of monitoring different process systems has been proven.

1.2 Problem Statement

Due to the surge in global demand for water, easily accessible supplies of water will no longer keep up with the demand in the future. Therefore, water treatment plants are becoming a widely used way of supplying water to different usage areas. The developing of an easy way to control these supplies is important for remote users and obsolete technologies have failed to cope with these demands. Therefore, new designs had to be introduced by instrumentation and control engineers.

1.3 Objective and Scope of Study

To develop a monitoring and control system for the reverse osmosis desalination water treatment plants. The SCADA System would be used for data acquisition, logging and control of the plant variables. The system should be easy to use and implemented on normal PCs in order to make the control and data acquisition more easy and cheap.

CHAPTER 2
LITERATURE REVIEW

2.1 Theory of operation

2.1.1 Reverse Osmosis

Reverse osmosis is a separation process that uses pressure to force a solution through a semi permeable membrane at high pressure. It is achieved when water passes through the membranes allowing water to pass and blocking the dissolved salts and solid particles from passing this happens by using pressure supplied from high pressure pump to overcome the osmotic pressure. To clarify more the concept of the whole process Osmosis is explained as water moving from low concentration solution to high concentration solution until equilibrium is achieved by natural osmotic pressure. In Reverse Osmosis we use the reverse of the natural process in order to filter the water and treat it. Figure 1 illustrates the chemical process:

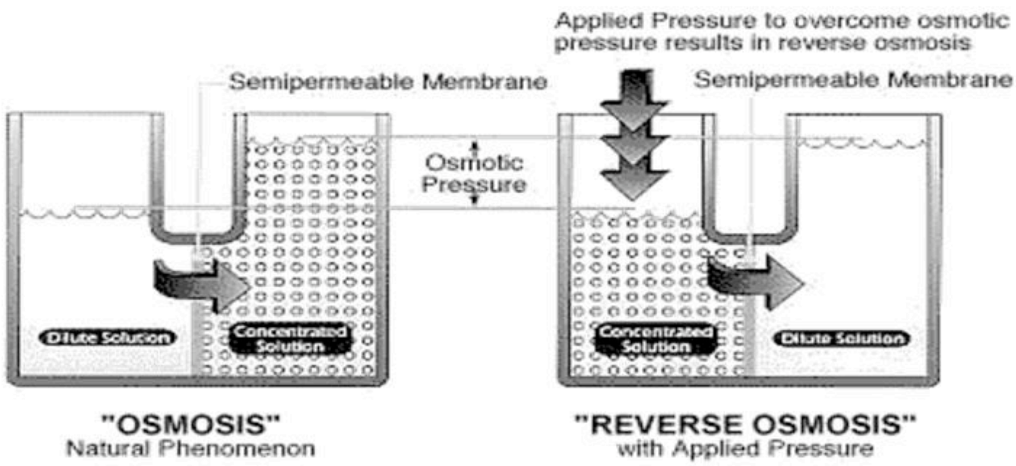


Figure 1 Reverse Osmosis Process [1]

Reverse Osmosis units is a selection of several components that vary according to the required product. The water is pumped from its raw source into the RO module, where it is treated with a polymer to initiate coagulation. Next, it is run through a multi-media filter where it undergoes ion exchange. It is then pumped through a cartridge filter which is usually spiral-wound cotton. This process clarifies the water of any particles larger than 5 micrometers and eliminates almost all turbidity. The clarified water is then fed through a high-pressure piston pump into a series of vessels where it is subject to reverse osmosis. The product water is free of 90.00% - 99.98% of the raw water's Total Dissolved Solids (TDS). [1]

2.1.2 DAQ Card & Labview®

The DAQ Card is a low-cost, low-power analog input, digital, and timing I/O card for computers equipped with a Type II PCMCIA slot. The small size and weight of the DAQ Card coupled with its low-power consumption make this card ideal for use in portable computers, making remote data acquisition practical.

LabVIEW is an innovative program development software package for data acquisition and control applications. LabVIEW uses graphical programming; the software includes extensive libraries for data acquisition, instrument control, data analysis, and graphical data presentation. It features interactive graphics, a state-of-the-art user interface, and a powerful graphical programming language. Figure 2 illustrates the interface between DAQ & program. [2]

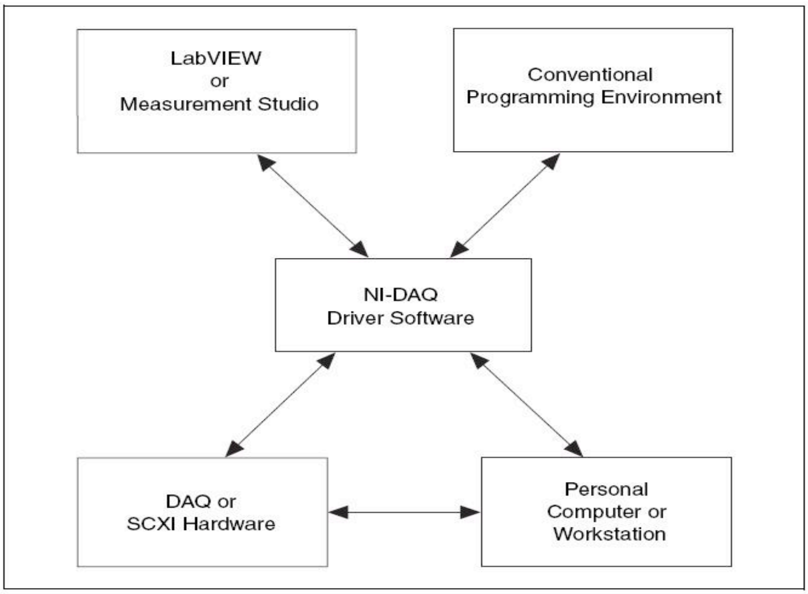


Figure 2 interface between DAQ, Hardware & Program

2.1.3 Data acquisition

Data acquisition is the sampling of the real world to generate data that can be manipulated by a computer. Sometimes abbreviated DAQ or DAS, data acquisition typically involves acquisition of signals and waveforms and processing the signals to obtain desired information. The components of data acquisition systems include:

1. Appropriate sensors that convert any measurement parameter to a corresponding measurable electrical signal, such as voltage, current, change in resistance or capacitor values

2. Conditioning the electrical signal which can then be acquired by data acquisition hardware. Acquired data are displayed, analyzed, and stored on a computer, either using vendor supplied software, or custom displays and control can be developed using various general purpose programming languages such as BASIC, C, FORTRAN, Java, Lisp, Pascal.

N.B: Specialized programming languages used for data acquisition include EPICS, used to build large scale data acquisition systems, LabVIEW, which offers a graphical programming environment optimized for data acquisition, and MATLAB which provides a programming language, and also built-in graphical tools and libraries for data acquisition and analysis.[3]

2.1.4 Lab View Software: (VISUAL SIMULATION)

Lab VIEW programs are called *virtual instruments*, because their appearance and operation imitate physical instruments, such as oscilloscopes and multi-meters. Lab VIEW contains a comprehensive set of tools for acquiring analyzing, displaying, and storing data, as well as tools to help you troubleshoot your code.

LabVIEW contain three components- the *front panel*, the *block diagram*, and the *icon* and *connector pane*.

In Lab VIEW, you build a user interface, or front panel, with controls and indicators. Controls are knobs, push buttons, dials, and other input devices. Indicators are graphs, LEDs, and other displays. After you build the user interface, you add code using VIs and structures to control the front panel objects. The block diagram contains this code. In some ways, the block diagram resembles a flowchart.

Use Lab VIEW to communicate with hardware such as data acquisition, vision, and motion control devices. Lab VIEW also has built-in features for connecting your application to the Web using the Lab VIEW Web Server and software standards such as TCP/IP networking and ActiveX.

Using Lab VIEW, you can create test and measurement, data acquisitions, instrument control, data logging, measurement analysis, and report generation applications. [10, 11]

2.2 Similar systems

2.2.1 The Oia Plant

In the Community of Oia in the island of Santorini in Greece, there is an RO desalination plant in operation. The plant contains two individual units with the production of 380 m^3 /d and 160 m^3 /d respectively. Matrix, USA commissioned both units in 1995 and 1998 respectively [4].

The fact that the current state of control and automation in small-size RO plants conspicuously lags behind contemporary developments in automation and remote control techniques has motivated a couple of engineers to develop a low cost Supervision Control and Data Acquisition (SCADA) system for the small size RO plant. Figure 3 shows the flow diagram of the plant:

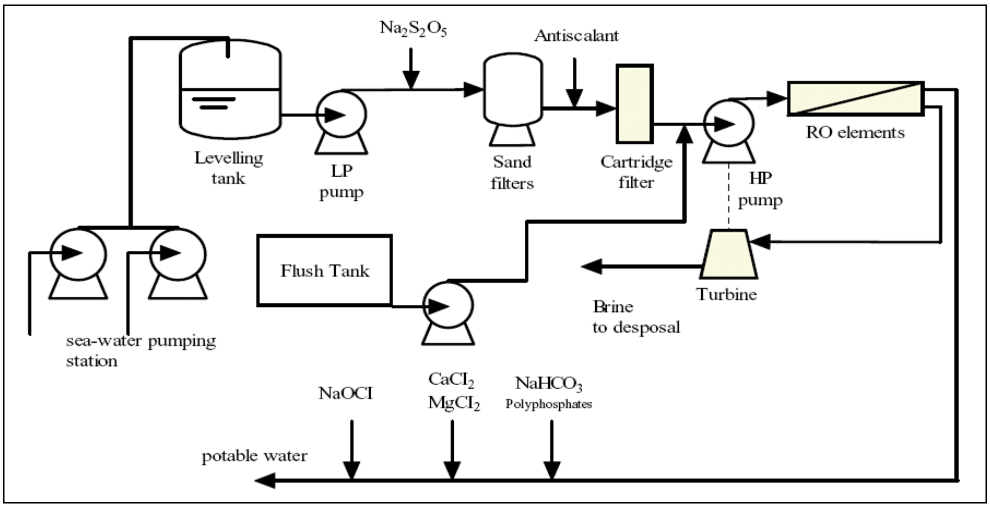


Figure 3 Flow Diagram of the Oia Plant [4]

The existing conventional automation system, common for most RO plants, could perform the following actions:

- Turn the plant on in a specific order
- Turn the plant off in a specific order
- Emergency stop
- Product conductivity control
- Low suction pressure control

- High discharge pressure control
- Antiscalants low level control
- Flush and clean the membranes

2.2.1.1 The new SCADA System:

Therefore in [4] the researchers illustrate how the new system would work in parallel with the conventional system in order to prove its advantages. The new system is illustrated in the text below quoted from the source:

"To labor productivity it was decided to install a PC based SCADA system. The introduction of an advanced automation system to the RO plant should be based on standardized, reliable, user-friendly, proven and modern technology. It was decided to install an advanced automation system, with the appropriate hardware, in parallel to the conventional one. The SCADA system should accomplish the following activities:

- Measure signals with the installed sensors
- Log, present and record them
- Control and manipulate the events of the desalination process by driving the same relays that the conventional automation drives to produce an action.

The SCADA System is then introduced using an Adam 4000 modules and the software is the VisiDaq 3.1. The System proved to be user friendly and low on cost. The main advantage of this system is its flexibility. The system can be very small to control a simple process and then to be enlarged by an addition of new modules according the needs of the particular application. On the other hand, different installations can be controlled and supervised by the same PC and program, since the modules can send signals to the PC from a distance up to 1200 m." The Design of the SCADA system is then introduced in figure 4:

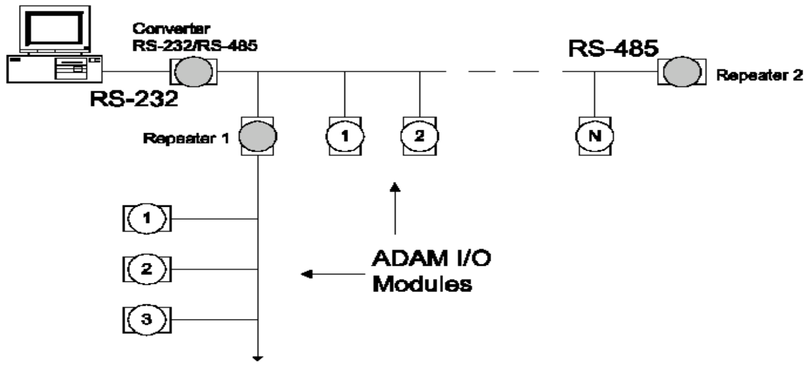


Figure 4 The Adam Series Module SCADA system for the Oia Plant. [4]

2.2.2 Seymour Reverse Osmosis Plant, TX, USA

At the end of 1998, Meco was awarded the contract for a reverse osmosis (RO) plant to provide primary water treatment for the City of Seymour. [5]

The decision to build a new treatment facility had been driven by growing concerns over the high levels of nitrates in water sourced from the Seymour aquifer and the potential implications this posed for public health, particularly amongst pregnant women and infants. The choice of RO technology was made on the basis of performance criteria, cost-effectiveness and the system's potential for meeting the increasingly stringent regulatory demands anticipated for the future.

Awarded on a turnkey basis, the contract also required the provision of control systems and ancillary items including bulk chemical storage and laboratory facilities. Funding for the facility was made available through a combination of grants and loans from the US Department of Agricultural Rural Development agency. Further contributions towards the cost of the plant came from the Baylor Water Corporation, a rural supplier, which now sends the water from its own wells, located in a nearby well field, to the RO plant for treatment. The overall project cost was $2.9 million.

Since being brought on-line on 24 February 2000, the plant has successfully improved the quality of the water supplied, bringing about both the intended reduction in the nitrate loading and providing softened water as an additional benefit. Although water costs to the customer have risen as a result, the 2,000 US gallon base rate increasing from the previous $8.25 to $13.10, the new charges are not significantly different from those levied by a number of other comparable municipalities.

2.2.2.1 The RO PLANT:

Designed around two parallel treatment trains, the plant has a nominal maximum potential continuous daily output of 7,600m³, though in practice it is currently only required to deliver around half that amount. At present, the population of Seymour is slightly in excess of 3,000. However, in order to permit the plant to be easily extended to meet expected future growth, the floor plan was designed from the outset with enough space to allow for the addition of a third train, which would then extend the facility's full capacity to11,400m³/day. [5]. Figure 5 shows the plant RO system:

Figure 5 The Seymor Plant membranes & cleaning system [5]

The raw water flow is pre-treated both chemically and by filtration to prepare it for RO treatment and to help protect the membranes from damage. The reverse osmosis system itself comprises two skids, each with a maximum rating of 45 liters per second. They are computer controlled so that their actual output responds automatically to demand. The product water is subsequently degasified, principally to reduce the dissolved carbon dioxide content, before being disinfected and then pumped into the distribution network.

The use of state of the art Programmable Logic Controller (PLC) controls, located in a separate climate controlled room, allows the entire operation to run with minimal supervision, permitting the operator to manage the entire plant from one control panel.

2.2.2.2 Plant SCADA System:

The SCADA system consists of 21 screens showing overall plant status, main menu, an alarm summary, feed-water and product water details, chemical systems status, operational trends and control parameters. Data logging is to an Excel spreadsheet which can be printed as required. A state-of-the-art communications network also allows the plant to be supervised and operated from MECO's New Orleans headquarters, nearly 670 miles away, if the need arises. Figure 6 shows the control room in the plant:

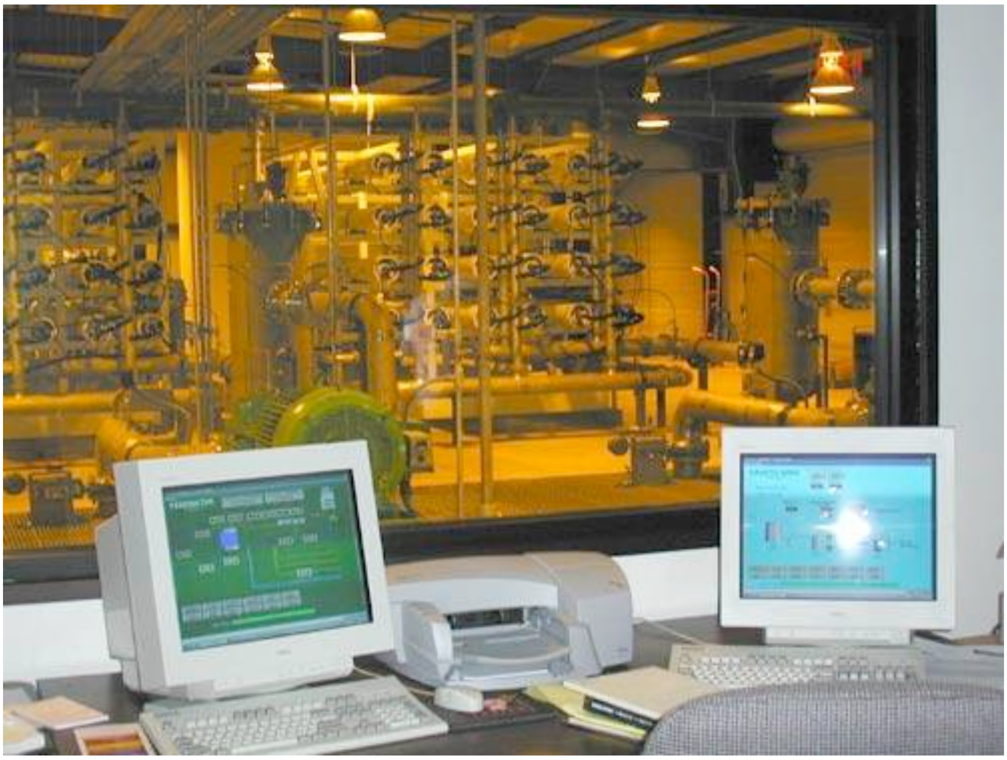


Figure 6 The Seymor plant SCADA system [5]

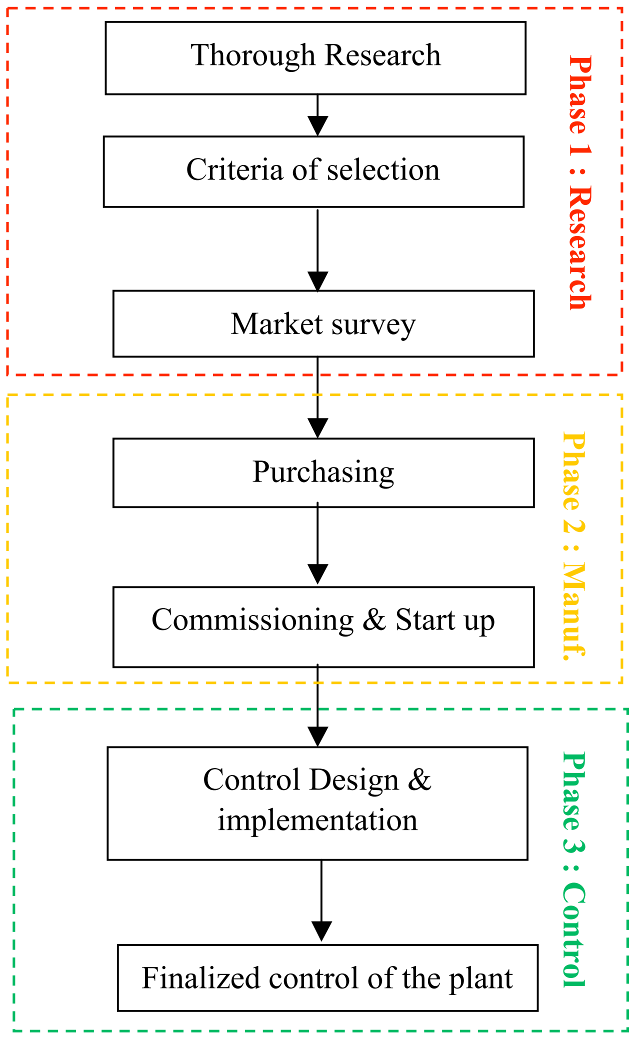
CHAPTER 3

METHODOLGY

The basis of this project is to design and build a laboratory scaled model of the full-sized RO desalination water treatment plant. The plant vital components are then connected to the DAQ card by which the data is acquainted and then a software (LABVIEW) is used to do further illustrations and analyze the data.

3.1 Project Phases

The project is divided into 3 main phases which is the research, manufacturing of the plant and the implementation of the control system.



3.2 Laboratory Scaled Model

For the Model to be easy built, the variables that should be monitored was determined then a downscale model was designed and then components had been purchased, the manufacturing part then takes place, the design had been discussed with the supervisor and the technician in order to know the capabilities of building such design in the lab.

3.2.1 Plant theory of operation

- Ro units use spiral wounded membranes mounted in high pressure containers called pressure vessels.
- The high pressure pump produces high pressure which must be greater or twice the osmotic pressure of feed water so the water will pass through the membranes which will block the passage of the dissolved salts and the solid particles so desalination is achieved.
- Pretreatment and post treatment is required to increase the efficiency and life time of RO unit.

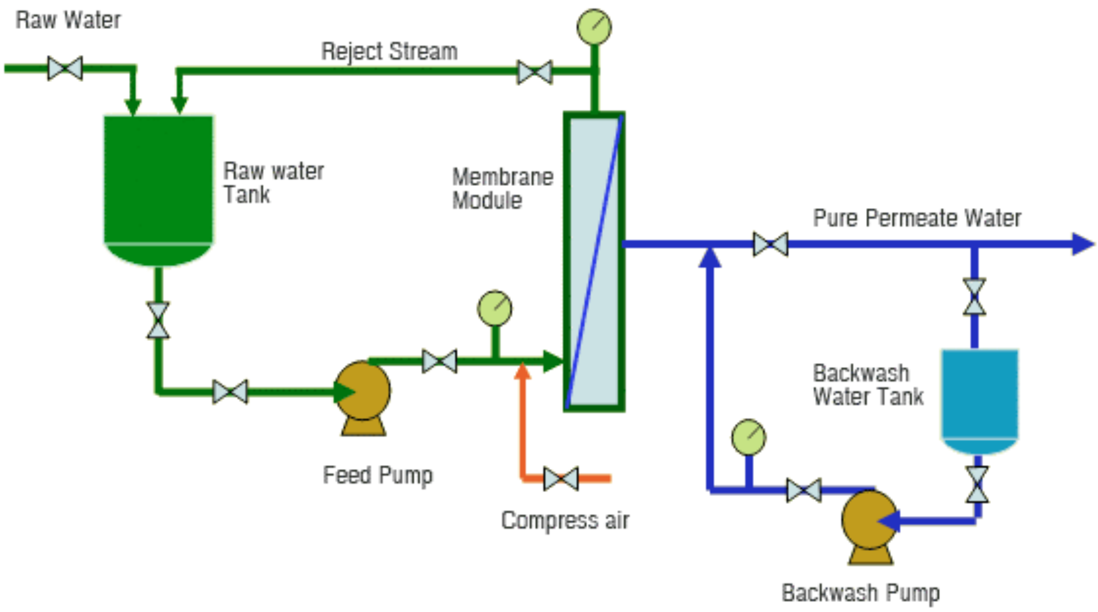


Figure 7 RO Unit

However due to limitations of budget and capabilities it was decided to enhance the design of the RO shown in figure 7 by cutting down the pretreatment part and some of the treatment section in order to be able to build the model and an enhanced design was proposed for the plant treatment part adding to that one post-treatment 5 micron carbon filter. The simplified design is elaborated in figure 8:

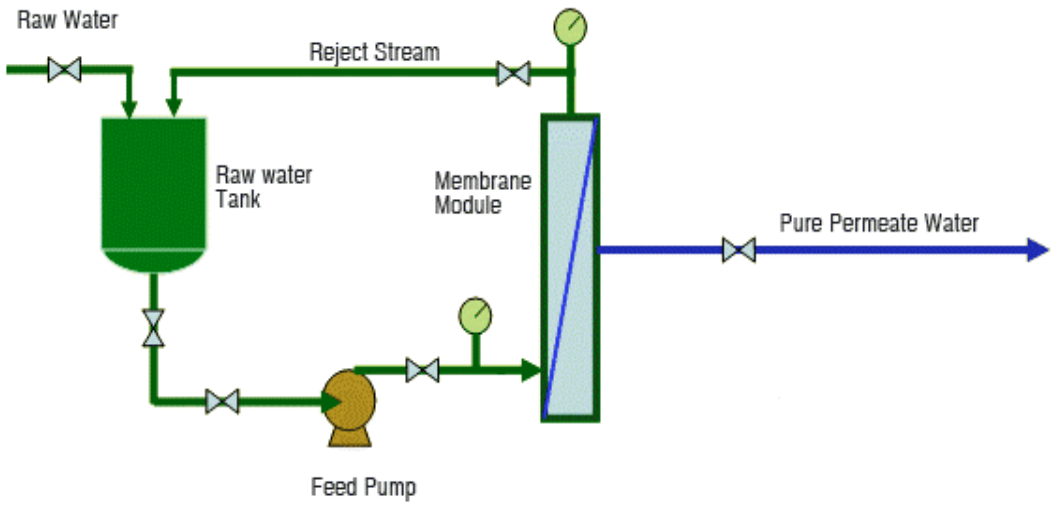


Figure 8 Simplified Design of treatment plant

3.2.2 Reverse Osmosis Unit Components

The components as the RO design of figure 7 shows are mainly some mechanical pumps connected with filters and membranes of the chemical process this all is backed up by the electrical connections and instruments and the components would be listed as follows:

i. Pumps
ii. Membranes
iii. Pre-filters
iv. Post filters
v. Valves
vi. Dc motor and starters
vii. Pressure vessels
viii. Skid(housing the system is mounted on)

3.2.3 Unit's Components functions and types

i. High Pressure Pumps:

Pumps are essential in any RO unit; where it is the main source of pressure to exceed feed water osmotic pressure in order to produce permeates water.

There are to two types of Pumps that can be used in R.O. Unit:

- Positive Displacement Pump.
- Reciprocating Pump.
- Rotary Pumps.
- Centrifugal Pumps.

ii. Membranes:

Membranes used in reverse osmosis are, in general, made out of polyimide, chosen primarily for its permeability to water and relative impermeability to various dissolved impurities including salt ions and other small molecules that cannot be filtered

Types of membranes:

- Spiral wound
- Hollow fine fiber

Membranes are made of:

- Cellulosic
- Aromatic Polyamide
- Thin Film Composite

iii. Pretreatment

Pre-treatment is important when working with RO membranes due to the nature of their spiral wound design. The material is engineered in such a fashion to allow only one way flow through the system. As such the spiral wound design doesn't allow for back pulsing with water or air agitation to scour its surface and remove solids. Since accumulated material cannot be removed from the membrane surface systems they are highly susceptible to fouling.

iv. Post-treatment

Post-treatment is done using chlorine and caustic soda.

Post-treatment is the treatment of the permeate water in order to meet the recommended product water specification according to the law of country.

Objectives of the post-treatment:

- PH adjustment
- Sanitization (chlorine not less than 0.5 mg/lit)

v. DC motors and starters

Dc motors is the prime mover of the pump as it changes the electric power (volt) to rotary motion (torque & angular velocity) this torque is driven to the pump by mechanical coupling.

vi. Valves:

Valves are used to regulate the flow of the water throughout the process it's a final control element from which flow variable can be controlled

Types of valves that can be used in the RO unit:

- Two way valve
- Solenoid valve

vii. Pressure vessels:

The RO pressure vessel maybe constructed of a fiber glass-reinforced polyesters or vinyl ester material or stainless steel .the selection of the material will have an effect on the performance of the system.

The pressure vessel selected for the RO unit should stand the maximum working pressure to ensure maximum safety.

viii. Skid:

- It's the housing the RO unit is mounted in.
- It should be made of any tough material.

3.2.4 Control Design

The design of the control system is mainly hindered by the possibilities and budget of this project as instruments are well known for their relative high cost therefore the tight budget put some constrains in the design of the control system.

Figure 9 illustrates the total concept of the system and how it works:

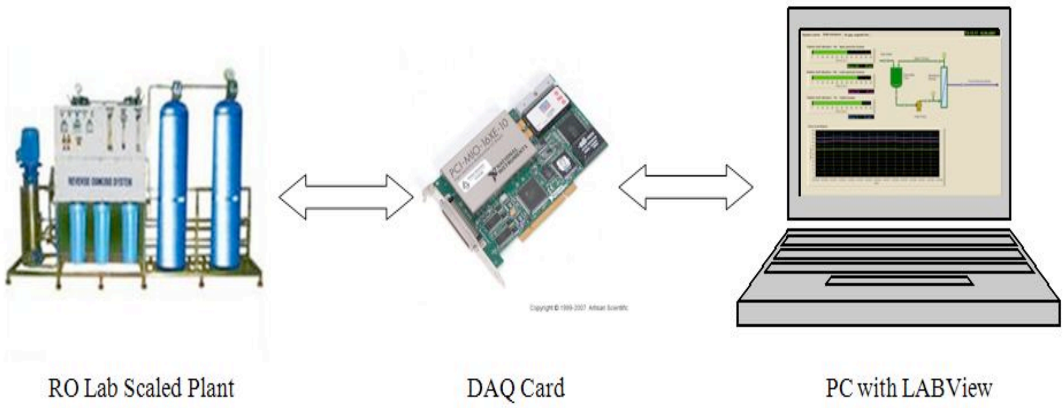


Figure 9 System illustration

3.2.5 Variables & Controllability

The three most important measurements for monitoring RO operation are flow, pressure and conductivity. Other important measurements include temperature, ph and oxidation reduction potential (especially for TFS membranes). Flow is extremely important because it will change if membrane foul or tear due to chemical or microbiological attack. Monitoring of flow rate, or perhaps more accurately, flow performance, is not a mindless task, as temperature directly affect the amount of water that will pass through the membranes. When water cools it becomes denser, and its passage is restricted through the membranes. At the same pump pressure, flow may decrease by almost 50 % when the influent temp drops from 77˚ F to 50˚F conversely the flow may increase by 10 % with a 10 degree rise in temperature above 77˚F a conversion calculation must be included in any flow measurements, this called normalizing the flow rate .without this correction, it would be difficult to accurately determine whether change in flow rate was related to temperature or a system or membrane upset. Membrane manufacturer's supply normalizing calculations that allow the operator to accurately normalize flow rates. [6, 9]

3.3 Estimated Cost

Estimating the whole cost of the project would be braked into 3 main parts:

1. The Reverse Osmosis Small Scale Unit
2. The instrumentation & Control devices.
3. The monitoring PC & Software

However there are real costs and estimated costs as some things would be provided by the university's lab. Putting in mind that the whole project's idea is the control of the reverse osmosis system not the process itself therefore if we need to calculate the real cost of the project and implement it in real life it would be only the instrumentation & control devices and the monitoring PC.

As for this project building a process mimic was essential due to the lack of one in the university and adding to that the instrumentation & control devices while the monitoring PC was supplied by UTP.

3.3.1 Preliminary Estimated Cost

For the small scale lab RO Unit:

Table 1 RO Unit estimated Cost

	Quantity needed	Est. cost per unit	Sum
Pumps	1	RM 150	RM 150.00
Membranes	1	RM 60	RM 60.00
Vessels	2	RM 40	RM 80.00
Piping & Skid	1	RM 150	RM 150.00
Summation			RM 440.00

For the Instrumentation & Control Devices:

Table 2 I & C system estimated Cost

	Quantity needed	Est. cost per unit	Sum
Pressure & Flow Sensors	3	RM 400	RM 1200.00
Manual Valves	3	RM 10	RM 30.00
Auto Valve on/off	1	RM 60	RM 60.00
DAQ Card & Connections	1	USD 800	RM 2800.00
Summation			RM 4090.00

For the Monitoring PC & Software:

Table 3 Misc estimated cost

	Quantity needed	Est. cost per unit	Sum
PC	1	RM 2000	2000.00
Labview ® Software	1	N/A*	N/A
Summation			RM 2000.00

* Included in the DAQ Card package

3.3.2 Real Cost

The estimated Cost is just a preliminary study on the whole project components with some market surveys and consultation from technicians, However it doesn't reflect the project's budget as in the implementation period PCs, instrumentation devices and DAQ cards was provided by the university therefore the main cost was reduced tremendously as they are the main players in the budget.

Also the design was enhanced according to the availability of components in the university and constrains of the budget factor as only RM 500 is allocated for the project. Therefore the real cost as a final cost after enhancing the design of the control system and the mimic itself was estimated as follows:

For the small scale lab RO Unit:

Table 4 RO Unit Real Cost

	Quantity used	Cost per unit	Sum
Pumps	1	RM 150	RM 150.00
Membranes	1	RM 60	RM 60.00
Tanks	2	RM 30	RM 60.00
Piping & Skid	1	RM 150	RM 150.00
Summation			RM 420.00

For the Instrumentation & Control Devices:

Table 5 I & C system Real Cost

	Quantity Used	Cost per unit	Sum
Level Sensors	2	RM 40	RM 80.00
Manual Valves	1	RM 10	RM 10.00
Level Control Device	1	RM 80	RM 80.00
DAQ Card & Connections	1	0	RM 0.00
Summation			RM 170.00

For the Monitoring PC & Software:

Table 6   PC & Software Real Cost

	Quantity used	Cost per unit	Sum
PC	1	RM 0	0.00
Labview ® Software	1	N/A*	N/A
Summation			RM 0.00

* Included in the DAQ Card package

CHAPTER 4
RESULTS AND DISCUSSION

This chapter discusses the product manufacturing part and the control system implementation.

Work on the purchasing the plant components, manufacturing and testing have been done on a parallel basis with the learning process about the control system used, implementation ,purchasing and setting it up.

4.1.1 Purchased plant components

The Reverse osmosis plant components were identified and purchased in order to build the model as follows:

- Diaphragm pump:
  Model (shown in figure 10): SHURflo RO Booster Pump, 24 VAC, 50 GPD, 38 FNPT

Figure 10 SHURflo booster pump

  Description:
  SHURflo 8000 Series RO Pumps are the most widely used pumps for RO. They are ideal for high pressure / low flow applications with low amp draw. They can be mounted in any position, are compact, and are designed for long trouble-free life.
  Technical information: Please find in appendix D

- Carbon filter (5 micron) :

Figure 11 Carbon filters

  Description: Micro-Sentry wound cartridge removes solids from liquids, compressed air or gases, the Micro-Sentry Cartridges have been nominally rated to exceed 98% efficiency, wound Cartridges can hold up to 300% of their weight in impurities at 30 PSI. Shown above in figure 11.

- Reverse Osmosis membrane :
  - Type of Membrane (Filmtech) as shown in figure 12
    - Nominal Active Surface Area **:** 36 ft2 3.3m2
    - Permeate Flow Rate: 900 GPD, 2.5 L/m.

Stabilized Salt Rejection: 99.5 %

Figure 12 RO Membrane

4.1.2 Manufactured lab scaled model

Manufacturing the lab scaled model was a success after all the research done and the equipment purchased a design was made in a 3D model on the AUTOCAD software in order to make it easier to manufacture the model. Figure 13 shows the design in 3D.please find in Appendix B the detailed CAD drawings.

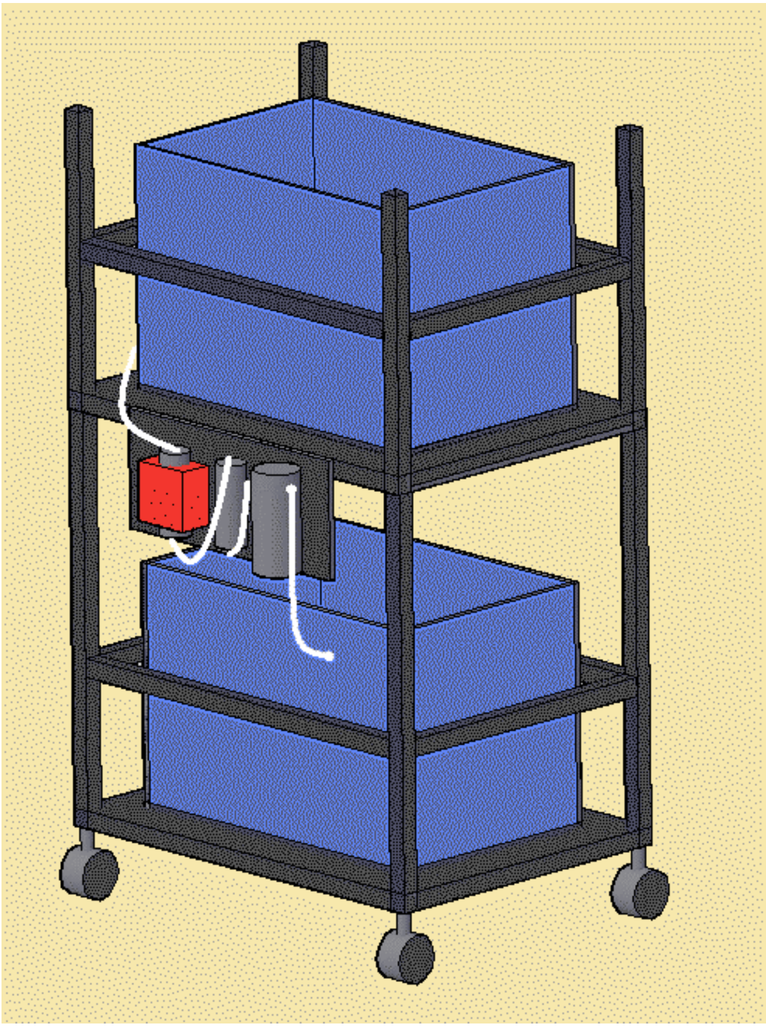


Figure 13 3D view of the lab scaled model

The skid was then manufactured using metal and black paint, the tanks were purchased and the plant equipments were all put together to produce the Reverse Osmosis lab scaled plant.

Figures 14 & 15 show the system after it was put together:

Figure 14 filters and membrane connected with the tanks

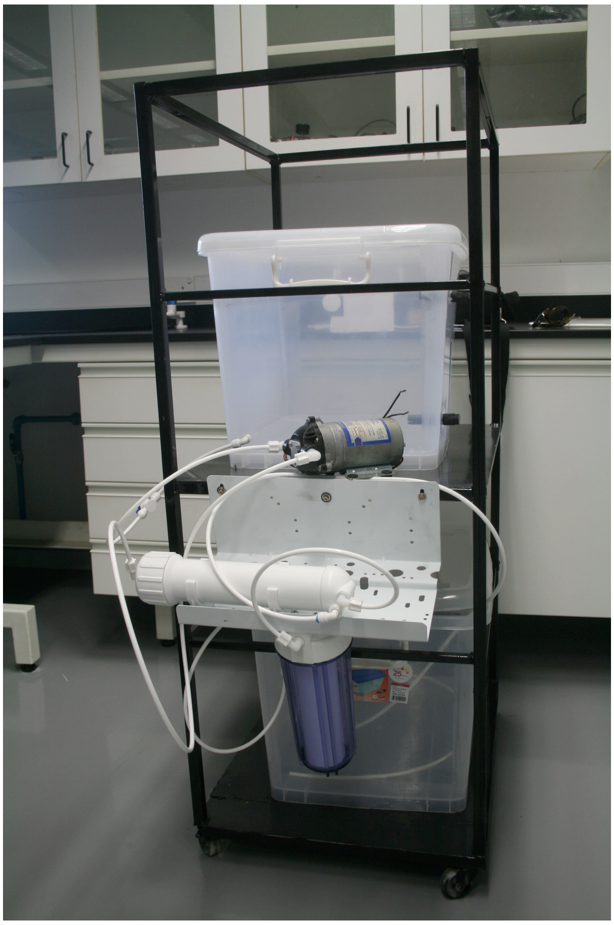


Figure 15 The Lab scaled RO Plant

4.1.3 Control system design

The proposed control system that is connected with the PC (shown in figure 16) is then designed in order to purchase the needed control devices a simple diagram that is shown in the following figure was made up in order to make it clear what components are needed and how they would work with the DAQ system.

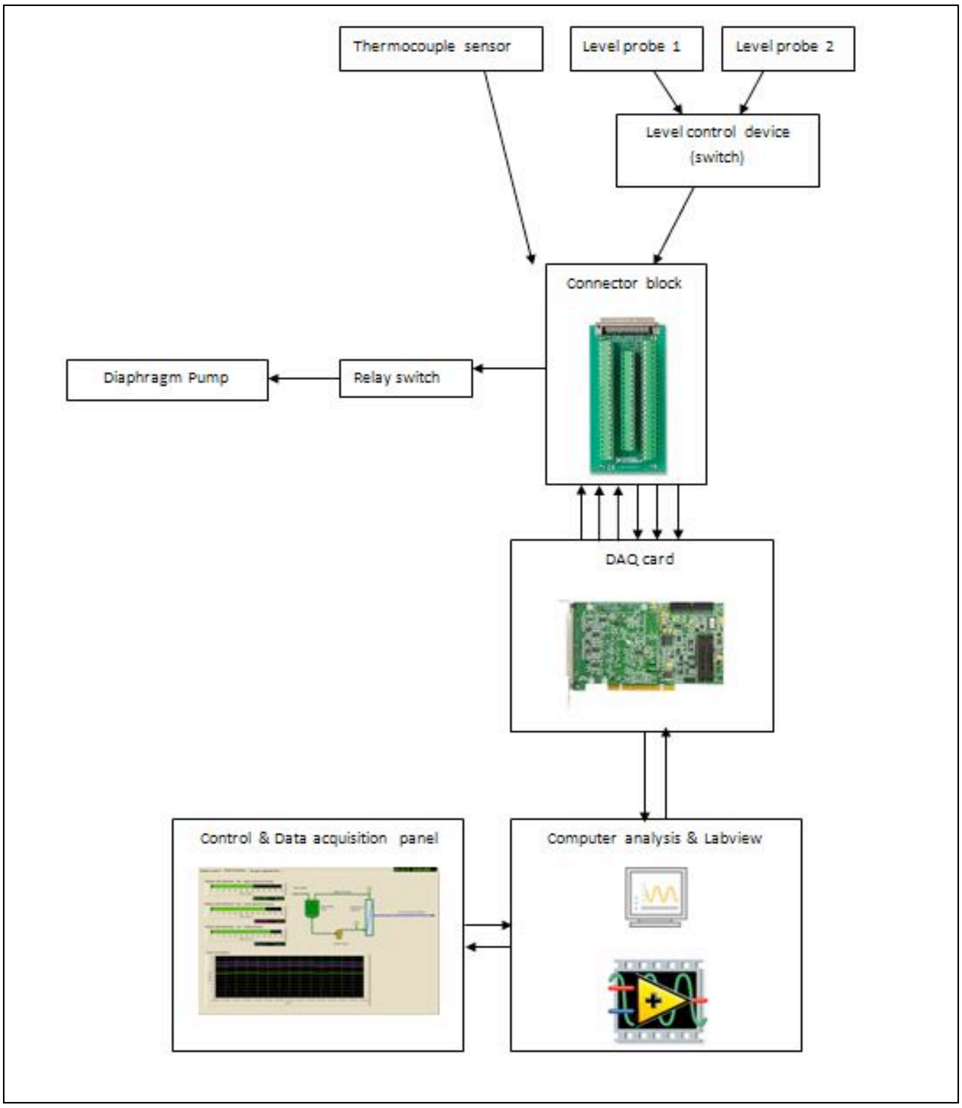


Figure 16 Proposed control system

The system is made up of 2 level sensors mounted in the first tank connecting to a liquid level control device, a thermocouple type K mounted to the inlet tank as well all of these sensors are connected to the connector block made by national instruments, a relay switch as well is connected to the connector block on a dc output which is mounted on the pump circuit to control the pumping of water into the RO membrane.

4.1.4 Purchased control devices

Purchasing the control devices was made as the design was enhanced it was agreed on that monitoring the flow won't be possible as the equipment needed are beyond the budget constrain and as very sensitive materials would be needed to complete the project, therefore design was enhanced and alternative control devices were located.
It was agreed on controlling the level in the input tank using a level control device and the temperature of the same tank using a K type thermocouple. A relay as well would be connected on the pump circuit in order to control the pump operation; these devices were purchased as follows:

- K type thermocouple (shown in figure 17):
  Can be mounted using a screw on the input tank

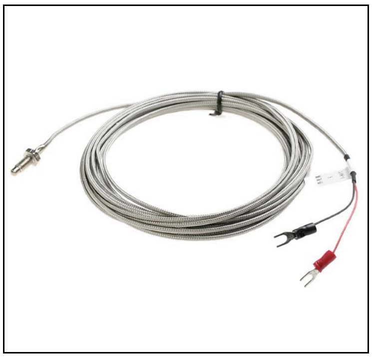


Figure 17 Type K thermocouple

- 2 level sensors probes
- A level control device switch (shown in figure 18):

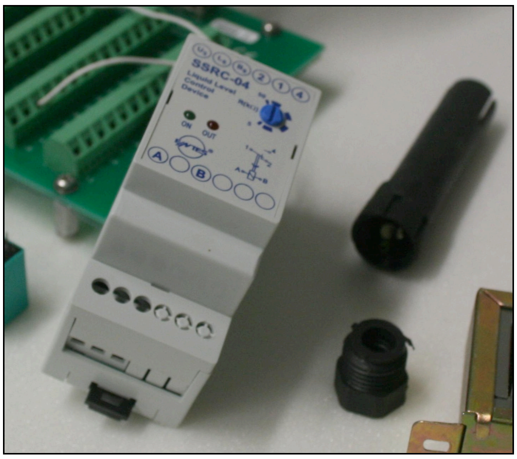


Figure 18 Level Control device with level sensors

- Relay switch of 6VDC switching operation and 240 VAC operation range (shown in figure 19):

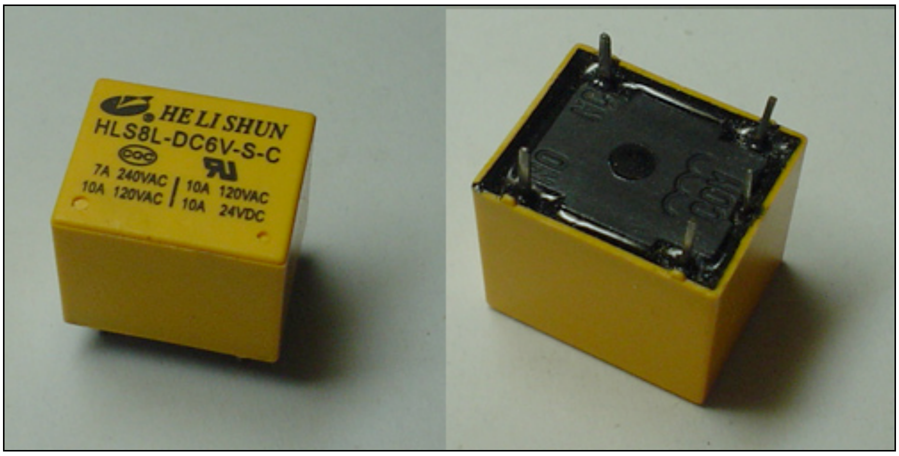


Figure 19 DC6V Relay Switch

4.1.5 Control System implementation and set up

The control system was then implemented using the purchased equipments. First wiring diagrams were made for equipments used. The connections are then made with the designated pins on the connector block shown in figure 20:

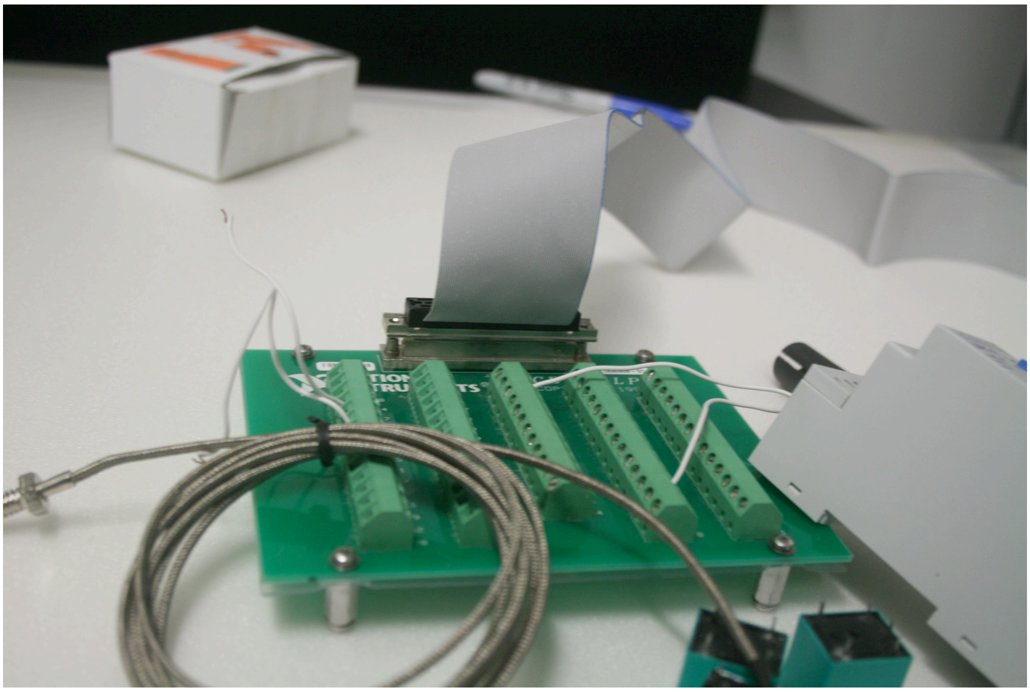


Figure 20 Connector block

Figure 21 shows the wiring diagram for the pump connected to the relay switch and power supply while the dc terminals of the relay are then connected to the digital output of the connector block.

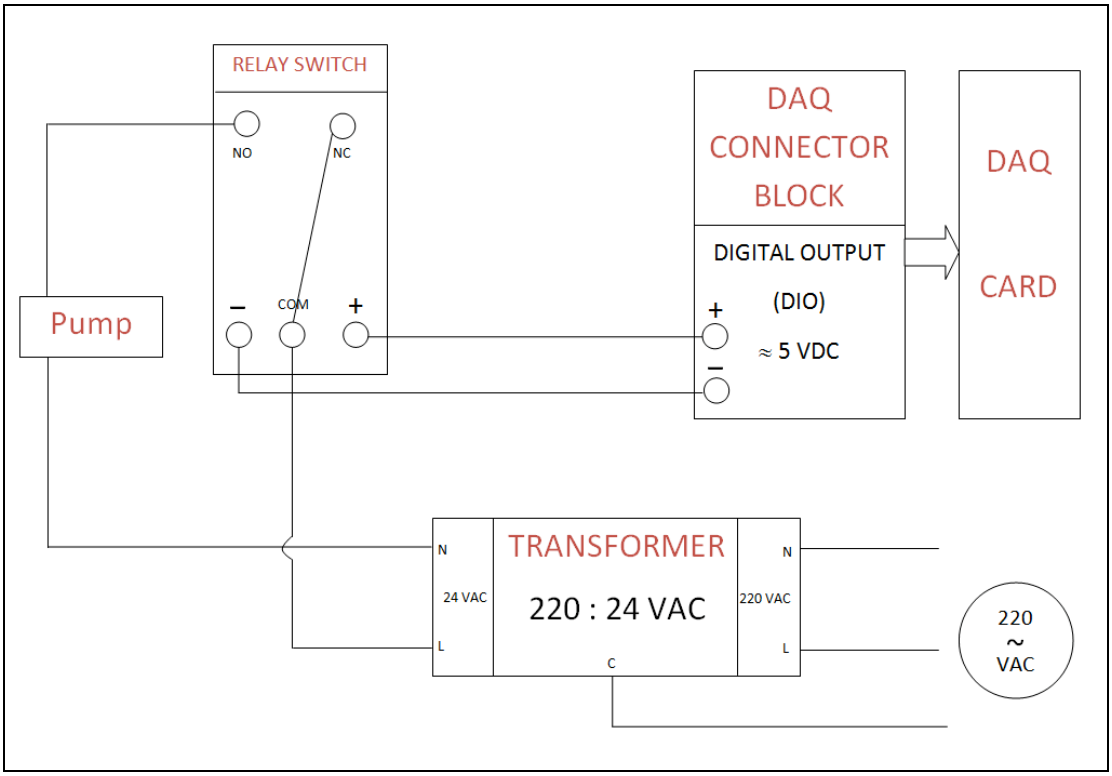


Figure 21 Wiring diagram of pump control

For the level control system figure 22 shows the wiring, where 2 probes mounted on the inlet tank is connected to a level control device which is connected to the designated pins on the connector block, power sources is connected as well.

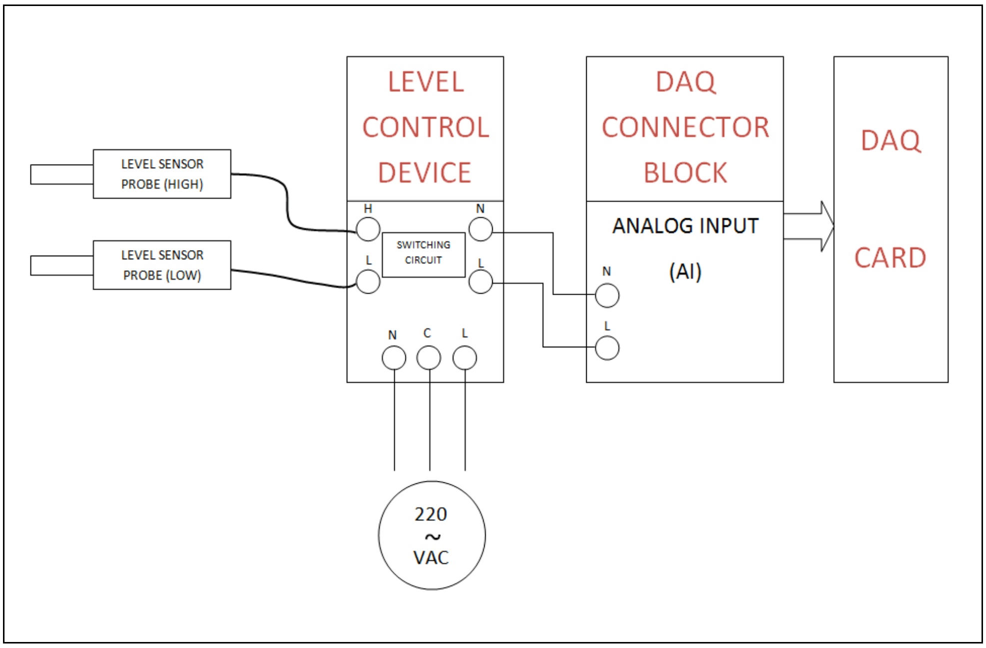


Figure 22 Level control wiring diagram

Thermocouples are also wired to the DAQ card in their designated analog input as shown in figure 23:

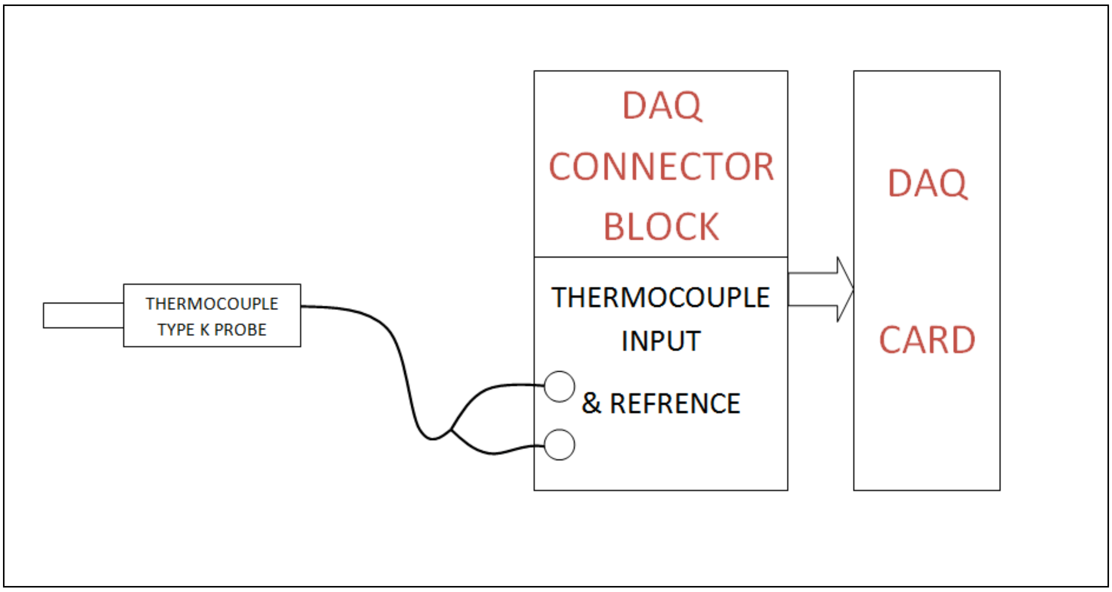


Figure 23 Thermocouple wiring circuit

4.1.6 Labview programming & Control panel design

The program is then used to design the controller using block diagrams. It is a graphical interface program and user friendly. For each instrument control block there would be a parallel interface in the front panel which will appear to the user of the control system.

Another software is used which is Measurement & automation Studio, it is used to assign each pin and create virtual instruments which is then exported to labview.

Figure 24 shows the block diagram designed to control the plant.

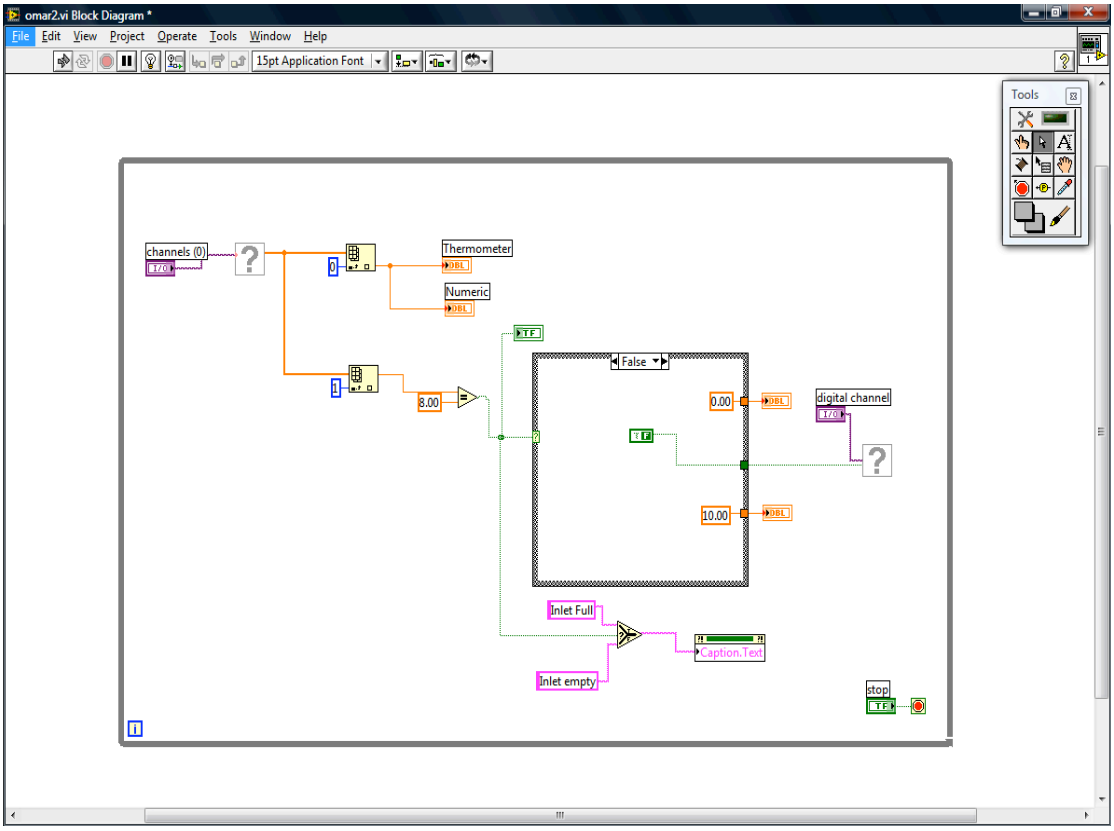


Figure 24 Block diagram of the program

The program is then finalized by designing a friendly front panel which can be used by the user and published on networks to be used in the control rooms as figure 25 shows:

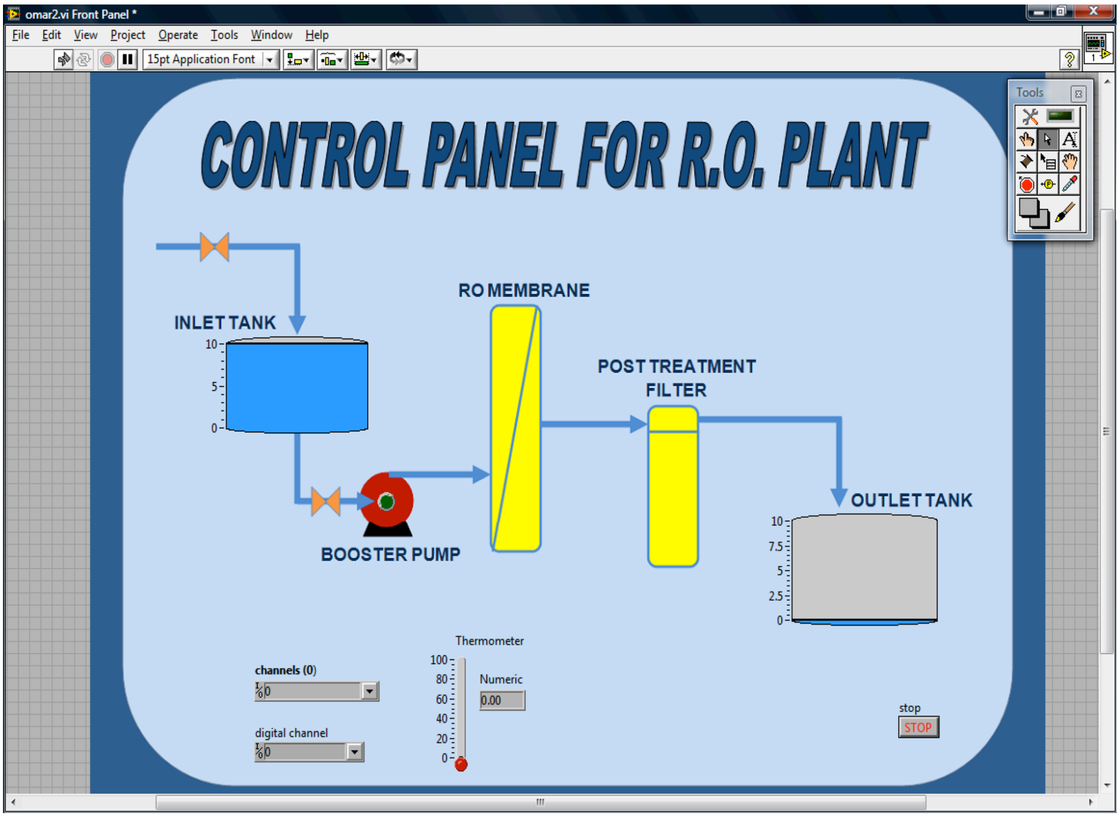


Figure 25 Front Panel

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The project has been a success in all fields, it gave a great lesson on how to manage a project individually from a to z, in all aspects of engineering experience has been gained from the cost engineering, mechanical design, chemical engineering and water treatment engineering, manufacturing engineering, electrical engineering and the core subject the control engineering.

Working on the process itself, estimating the cost and organizing the project was one of the best expertise gained. Electrical connections and designs have also played a big role in finishing up the product model.

The SCADA proves its advantages through the project comparing it to other conventional control systems. However costs might be high but as the product would be commercialized it would definitely affect the cost by dropping it down.

5.2 Recommendations

This system is just an example constrained by the project budget in order to give an idea of how SCADA would be a perfect choice for water supply especially in remote areas and if we have future prospect recommendations of this project it would be:

- Commercialization study:

  Where this project would be studied and enhanced to commercialize the product, costs would be reduced and enhancements would be made to the design.

- A full data acquisition of all the plant variables:

  This includes the TDS (total dissolved salts) as well as the flow measurements and other variables in order to make a full report on the plant and later on maintenance schedules can be estimated.

- A solar power supply system:

  Which would feed the plant with energy 24 hours a day using PV cells (photovoltaic), which if achieved would make this product a perfect choice for remote areas.

- Wireless DAQ:

  Where advanced models would be used in order to wirelessly monitor the plant and remotely control it easily and efficiently.

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[12] David Bailey, Edwin Wright, *Practical SCADA for Industry*, 2003 12-14.

APPENDICES

APPENDIX A
PROJECT GANTT CHARTS

Milestones for the First Semester of the Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9		10	11	12	13	14
1	Selection of Project Topic															
2	Preliminary Research Work															
3	Submission of Preliminary Report															
5	Project Work															
6	Submission of Progress Report															
7	Seminar (Compulsory)															
8	Project work continues															
9	Submission of Interim Report Final Draft															
10	Oral Presentation															

Suggested milestone

Process

Milestones for the Second Semester of the Final Year Project

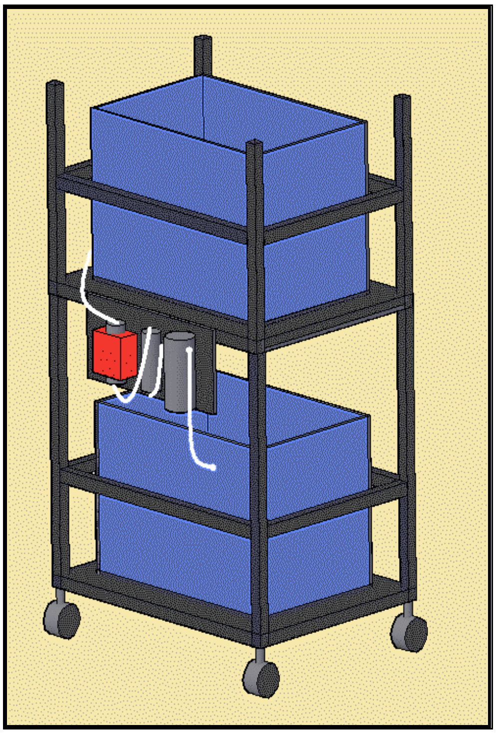
No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work Continue	■	■	■												
3	Project Work Continue				■	■	■	■								
4	Submission of Progress Report									●						
5	Project work continue									■	■	■	■			
6	Poster Exhibition											●				
7	Submission of Dissertation (Soft Bound)													●		
8	Oral Presentation														●	
9	Submission of Project Dissertation (Hard Bound)															●

● Suggested milestone

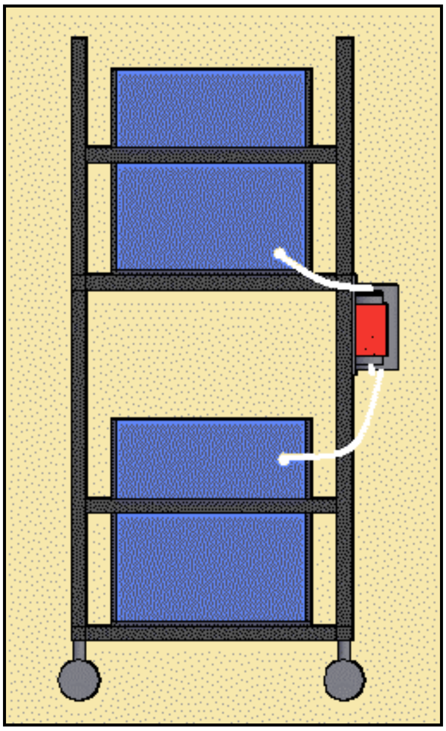
■ Process

APPENDIX B
PLANT DESIGN CAD DRAWINGS

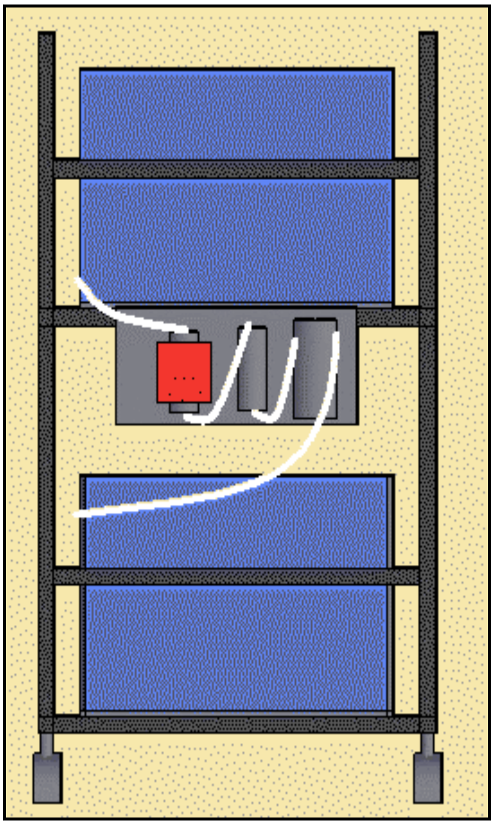
Different views of the lab scaled RO plant:



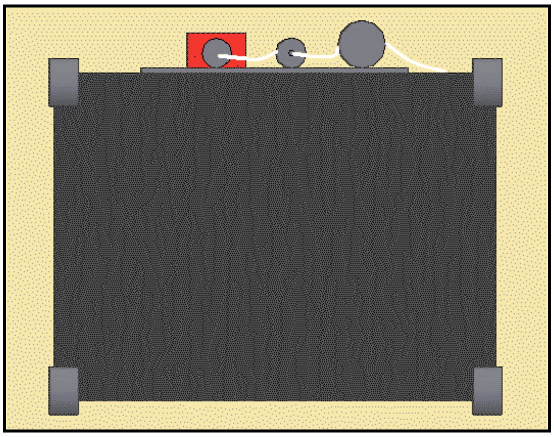
3D view



Side view



Front View



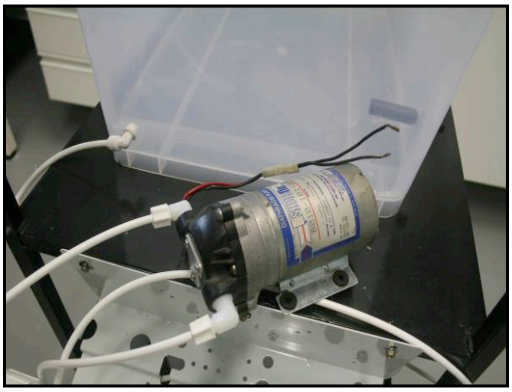
Bottom View

APPENDIX C

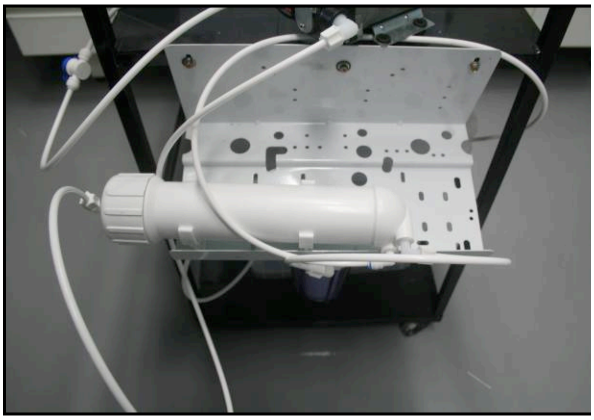
PLANT & CONTROL SYSTEMS PHOTOS

Some photos taken During Experiments:

RO Lab Scaled Plant

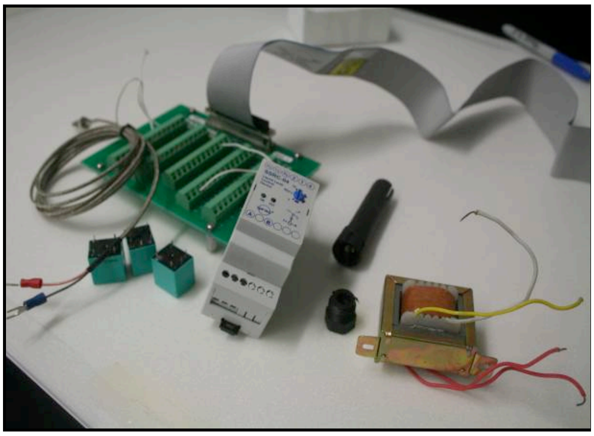


Shurflo Pump

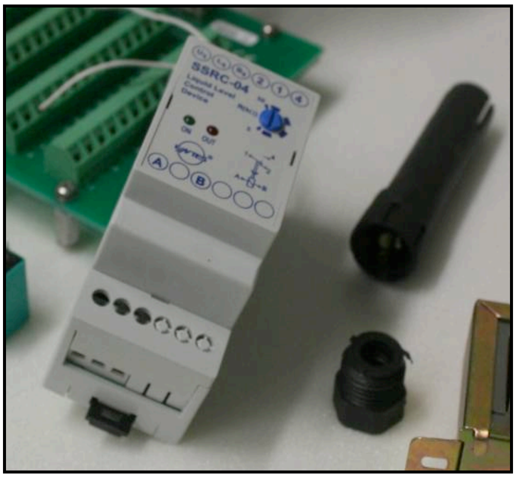


RO Membrane

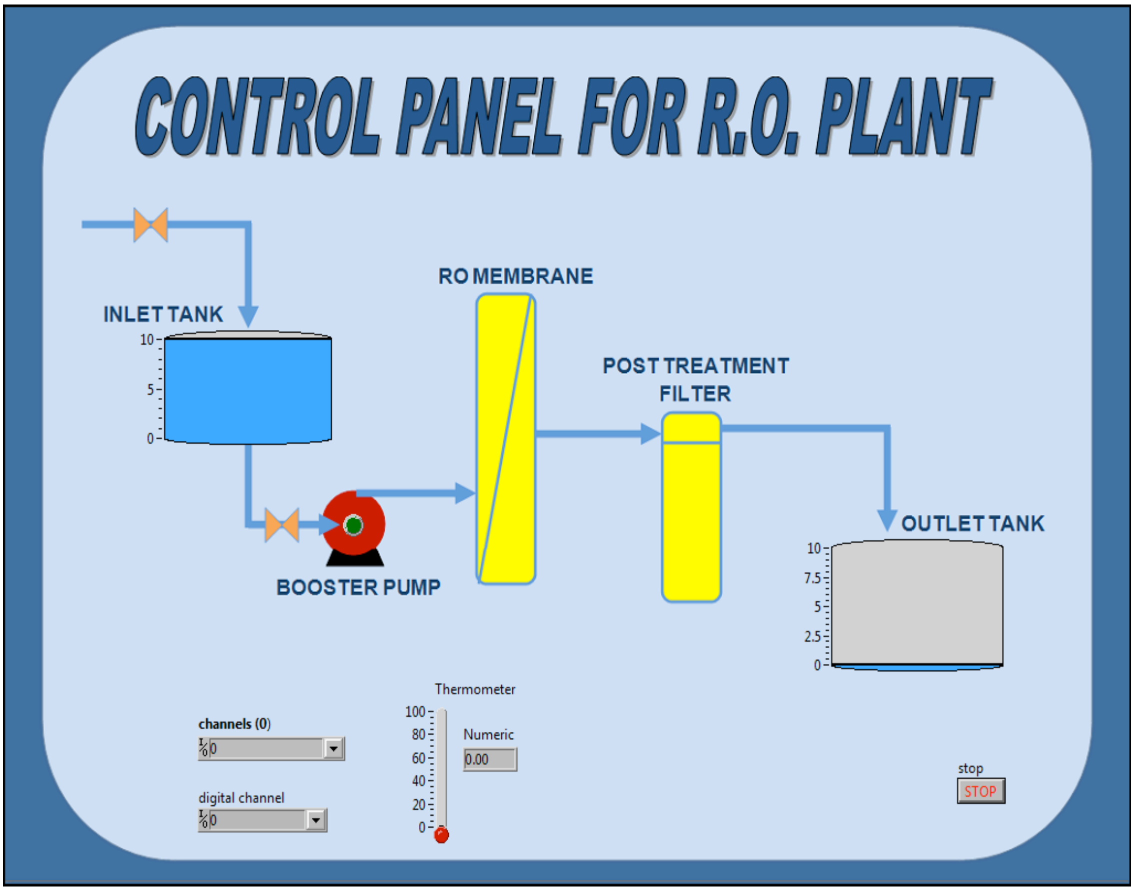
Post Treatment Filter



Connector Block and Devices



Liquid Level Sensor



Final Front Panel

APPENDIX D
PUMP TECHNICAL SPECS

SHURflo
First in Fluid Innovation

Depco Home

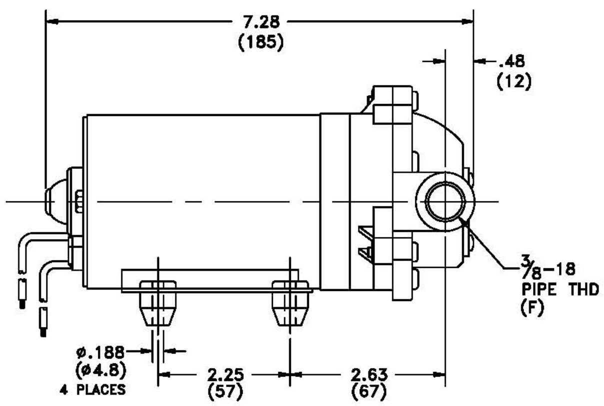
PRODUCT DATA SHEET
MODEL: 8010-101-200

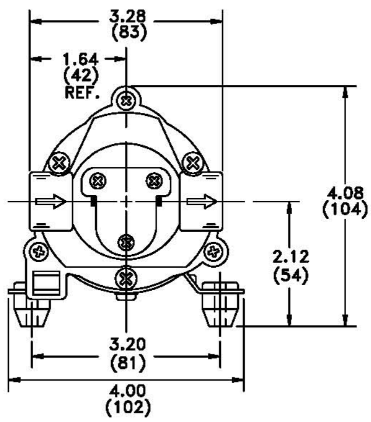
SPECIFICATIONS:

MODEL NUMBER: 8010-101-200
PUMP DESIGN: Positive Displacement 3 Chamber Diaphragm Pump
CAM: 2.0 Degree
MOTOR: Permanent Magnet, P/N 11-155-00
VOLTAGE: 24 VAC Nominal
PRESSURE SWITCH: None
LIQUID TEMPERATURE: 180 Degrees Fahrenheit (82 Degrees Centigrade) Max.
PRIME: Self-Priming Up To 4.0 Ft. Vertical,
Max. Inlet Pressure 30 PSI (2.1 Bar)
PORTS: 3/8"-18 NPT Female
MATERIAL OF CONSTRUCTION:
- **PLASTICS**- Polypro
- **VALVES**- EPDM
- **DIAPHRAGM**- Santoprene
- **FASTENERS**- Zinc or Cad Plated Steel

NET WEIGHT: 4.7 Lbs (2.13 Kg)
DUTY CYCLE: Continuous (See Temperature Rise Chart)
APPROVALS: N.S.F. Listed
TYPICAL APPLICATIONS: R.O. Booster Pump
BYPASS: 90 PSI Max.

DIMENSIONS:

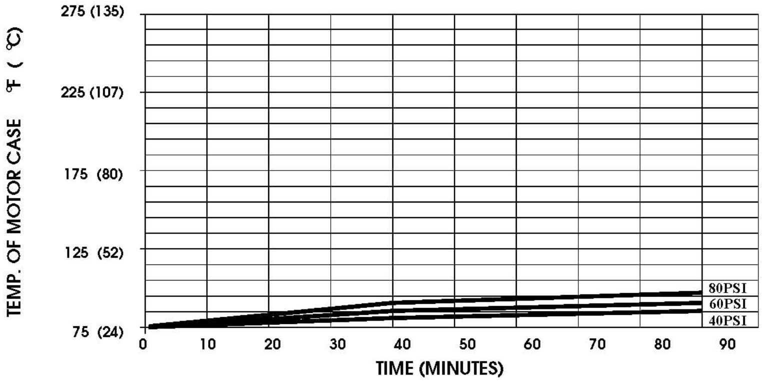




FILE # 8010-101-200 REVISED: 8/30/94 ISSUED: 2/17/92

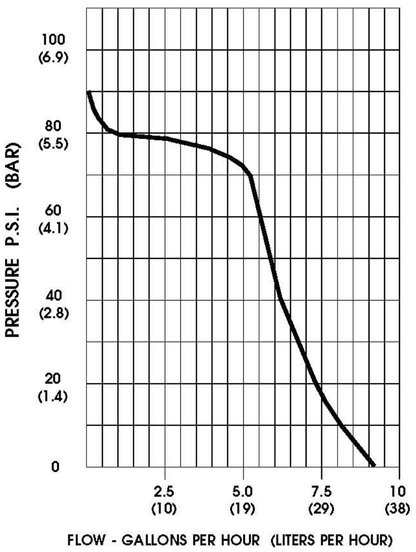
MODEL: 8010-101-200

TEMPERATURE RISE



THIS GRAPH IS FOR USE AS A DESIGN GUIDE. IT IS BASED ON RUNNING CONTINUOUSLY WITH AN AMBIENT TEMPERATURE OF 70° F IN STILL AIR.

TYPICAL PERFORMANCE



PRESSURE (PSI)	FLOW (GPH/LIT)	RPM MIN/MAX	CURRENT (AMPS)	VOLTAGE (VOLTS)
OPEN	9.20/38	470/475	0.17	24 VAC
10	8.30/31	450/455	0.19	"
20	7.52/28	430/435	0.21	"
30	6.87/26	415/420	0.25	"
40	6.33/24	395/400	0.27	"
50	5.91/22	380/385	0.31	"
60	5.48/21	370/380	0.34	"
70	5.17/20	350/375	0.37	"
80	0.60/2.3	345/375	0.41	"

-SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.
-ALL DATA BASED ON TESTING WITH WATER.

5900 KATELLA AVENUE, CYPRESS CA. 90630 (562) 795-5200 (800) 854-3218 FAX (562) 795-7554
SHURflo EAST, 52748 PARK SIX COURT, ELKHART, IN 46514 (219) 262-0478/(800) 762-8094/FAX 219-262-0478
SHURflo EUROPEAN DIVISION, LIBERTY HOUSE 105 BELL ST., REIGATE, SURREY, UNITED KINGDOM 44-737-242290/FAX 44-737-242282